Eurasian Griffon Vulture

Subjects: Biodiversity Conservation

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Among species of Gyps, the Eurasian griffon *G. fulvus* is the most widespread vulture across Europe, Asia and Africa, with a reproductive distribution extending from Kazakhstan and Nepal to southern Europe via the Caucasus. The species is now considered extinct as a breeding species in North Africa, where mainly records of nomadic juveniles or migratory overwintering adults are reported.

Keywords: genetic integrity ; species management ; anthropogenic impacts

1. Introduction

Human activities causing alteration of habitats, along with overfishing and hunting, intensive use of pesticide, herbicides and fertiliser in agriculture, the impacts of invasive alien species and climate change are the main causes of biodiversity loss for ecosystems [1][2][3][4]. Based on the latest report on the health of ecosystems, one million of plant and animal species are at risk of extinction because of human activities. Since the rate of species extinction has grown up to hundreds of times higher than in the past 10 million years, many of these species will become extinct within a few decades [5]. However, there are some species that have adapted to these changes and developed new behavioural strategies to survive in close contact with humans, as in the case of vultures. These birds have changed their eating habits by switching their primary food source to farm animals because carcasses of wild animals are scarce and even disappeared in some areas.

Vultures play a key role in maintaining the functioning and health of an ecosystem. As obligate scavengers, they deliver crucial benefits to humans by providing several ecosystem services, such as the regulatory one, which has gained more and more importance, especially in recent times with the spread of intensive breeding [6][7]. Indeed, vultures reduce the rates of transmission of infectious diseases quickly consuming domestic and wild animals' carcasses. Regarding this role of vultures, the provision of supplementary safe food at artificial feeding stations (SFFS) appears to be the most important management action applied to counter sanitary problems related to intensive breeding and to the conservation of these species sensitive to poisons or drugs present in contaminated carcasses [7][8][9][10][11][12][13][14].

Old World vultures living in Europe, Asia and Africa are members of the Accipitridae family and are closely related to raptors. The New World vultures' species from America belong to the Cathartidae family, which has been proposed by some authors as being evolutionarily related to Ciconiidae [15][16]. Because of convergent evolution, these two groups of vultures would have adapted their lifestyle to the same ecological niche, developing similar morphology and behaviour [17]. However, more recent studies have disproved the "cathartid-stork hypothesis" and pointed out a Cathartidae sister relationship with Accipitridae [18][19][20][21]. Both Old World and New World vultures are scavenging birds and feed mostly on carcasses of dead animals. Among the morphological and biological characters interpretable as adaptations are bare heads and neck to avoid pollution of feathers when feeding inside carcasses, strong hooked beaks with cutting edges to tear skin apart and feet more appropriate for movement on the ground than to catch prey [16]. A further adaptation is related to the feeding behaviour resulting in complex relationships at both intraspecific and interspecific levels during carcass exploitation [22][23][24][25]. The species of both families developed a static soaring style, perfectly optimised for searching for food over wide areas minimising the energy expenditure. Vultures rely heavily on soaring flight using air thermals [26].

Based on the "IUCN Red list for birds" [27], 11 out of the extant 16 Old World vultures' species are classified as globally threatened (eight Critically Endangered and three Endangered), while among the seven New World vultures' species, only two are at risk (one Vulnerable and one Critically Endangered). The causes of the decline of vultures are well known and it is necessary to urgently coordinate and implement the action plan in all its components [28]. In this entry, researchers retrace the evolutionary history of vultures, with particular emphasis on the Eurasian griffon vulture Gyps fulvus , and analyse their adaptation to habitat changes, providing useful information for a better management of this species.

2. The Eurasian Griffon Vulture: Ecology and Behaviour

The relationship between the use of feeding sites by avian scavengers and the trophic requirements resulting from the life-cycle phase and individual activities has been pointed out [14][22][29]. Given the considerable parental investment of vultures during their lengthy breeding period [30], they optimise the time spent on searching and obtaining food. In fact, during the incubation and chick-rearing phases, couples attend sites where the food is more predictable and accessible [22].

Gyps fulvus is one of the most sensitive avian species to reductions in food supplies [31]. The drop in the amount of food provided by extensive livestock herds has led to an intensification of the consumption of food by vultures at predictable feeding stations. The link between the food supplied at feeding stations and the increase in antibiotics and in Non-Steroidal Anti-Inflammatory Drugs (NSAID) in plasma and carcasses of the Eurasian griffon vulture has been evidenced [32][33]. The European Medicine Agency (EMA) recognised the risk for Gyps vultures from the use of NSAID in animals whose carcasses could be available as food to avian scavengers [34] and several proposals have been carried out to overcome this problem, such as the implementation of control systems, the use of alternative vulture-resistant drugs [28][35][36] and the so-called “One Health Approach” that promotes environmental responsibility and stimulates collaboration between veterinarians, pharmacologists, biologists and ecologists for the health of humans, animals and the environment [37].

To locate food directly, griffon vultures do not use a sense of smell but rely on vision [38]. The griffon has excellent eyesight and in flight can spot an animal carcass from a great distance, and when an individual locates a carcass, lowering its legs, it sends a signal to prepare for landing [39]. The entire carcass is eaten starting from the mouth and anus, in a relatively short time. Observations carried out by Spanish ornithologists have shown how a group of ~30 individuals can identify a carcass in a very short time (2–3 h) and consume a sheep in half an hour [40].

Vultures have one of the most effective immune systems that evolved to protect them from the daily exposition to factors affecting transmission of contagious diseases, such as those deriving from the consumption of the carcasses that produce pathogens and high toxic molecules. The immunity to pathogens present in carcasses is provided from an efficient digestive tract with a low pH value ranging from 1 to 1.5 [41] where, in symbiosis, lives a huge number of bacteria constituting the microbiota producing a bacteriocin with remarkable antimicrobial activity [42]. The presence of the microbiota is the result of the evolutionary ecological strategy for the exploitation of animal carcasses and, consequently, appears to be crucial in conferring protection against pathogens and for survival of the griffon [43]. For these reasons, vultures can also act as a reservoir of pathogenic zoonotic bacteria that can be transmitted to other animal species, increasing their diffusion in wildlife [44][45].

3. Eurasian Griffon Population Expansion and Decline

The availability of animal carcasses and predation residues was fundamental in determining the evolutionary success of the griffon and defining their role as specialised birds in recycling of biomass, in alternative to capturing and killing prey. These birds play a crucial role in keeping ecosystems healthy by contributing to carcass removal, limiting diseases transmission and providing indications of environmental contamination in relation to the quantity of pollutants deposited on their wings [46].

In the past, the main source of food for vultures derived from carcasses of wild animals which, in great numbers, populated most of the habitats overall the world. The Neolithic expansion of human people, the birth of agriculture and animal domestication had a strong impact on the distribution of wild animal populations, changed their natural habitats and caused the extinction of the megafauna. These events led to a continuous reduction in the availability of habitat for wildlife species and therefore, the carcasses of domestic animals such as small ruminants, cattle, pigs and horses became the main source of food for vultures. This phenomenon was particularly evident in Europe, where the vulture drastically changed its habits, switching to a diet almost exclusively based on domestic animal carcasses [12]. A different scenario occurred in Asia and, particularly, in Africa where domesticated cattle was lower in number compared to wild ungulate populations [47][48]. At first, the presence of livestock farms ensured a wide and continuous availability of food, thus creating the conditions for a demographic expansion of the vulture species. However, the dependence on livestock as a primary source of food raised several problems which synergistically led to the decline of vulture populations [49]. Once widespread across the continent, the Eurasian griffon population began to drastically decrease at the beginning of the last century in various European regions such as Italy and France, South-Eastern Europe, the Middle East and throughout the territory of North Africa. The causes of this decline have a single common denominator represented by the expansion of human activities and the emergence of related problems [50]. The alterations are manifold and include fragmentation of the territory for the construction of roads and wind turbines, implementation of new intensive forms in animal breeding, changes in sanitary policies as a result of diseases such as the bovine spongiform encephalopathy, the high diffusion of climbing activity, obsessive photographic hunting, the uncontrolled environmental pollution systems and the disturbing warming of the planet [12].

It has been revealed that the use of veterinary drugs such as NSAID and antibiotics used in livestock treatments that are toxic to Gyps severely affect populations of the Old World vultures [35][37][51][52][53][54][55]. Moreover, the use of poisonous compounds for the fight against stray dogs and against predators of domestic animals such as foxes play a more harmful role [51][56].

In parallel, after the outbreak of bovine spongiform encephalopathy, in 2001, European health policy banned the abandonment of livestock carcasses in the field, and consequently, the availability of food resources declined in some regions by more than 80% [57][58][59][60].

4. The Eurasian Griffon Vulture: Phylogeny and Genetic Diversity

In a recent study on the mitochondrial D-loop variability of the griffon vulture populations from the Mediterranean islands of Crete, Cyprus and Sardinia, Mereu et al. [61] identified a new haplotype (Hpt D) in the Cretan population. Both in Sardinian and Cretan populations, three haplotypes were detected, two shared (Hpts A and C) and one exclusive to each population: Hpt B in Sardinia and Hpt D in Crete. On the other side, a single haplotype (Hpt A) was found in the Cyprus population. Based on these data, the authors supposed that the higher genetic variability detected in the Cretan and Sardinian populations is the consequence of an evolutionary process affected by long isolation times while the Cypriot colony probably underwent a drastic bottleneck which only the Hpt A survived. The colonisation of these islands would have been characterised by several arrivals of individuals spaced out over time which could have replaced or contributed to enrich the pre-existing gene pool, up to determine the current genetic variability and different expressiveness of the four mtDNA haplotypes among the three populations analysed.

In 2002, Mira et al. [62] developed five microsatellite markers for the Eurasian vulture G. fulvus , providing new molecular tools for population genetic studies and for designing strategies in conservation and reintroduction projects.

A few years later, the first investigation by means of microsatellite markers was carried out on a network of native and reintroduced Griffon vulture populations successfully restored in Southern Europe, including the native colonies of Israel, Croatia and French Pyrenees (Ossau), one established reintroduced colony in France and four captive founding groups [63][64]. The genetic diversity estimations were similar in all native and reintroduced populations, and overall higher than those measured for other species of vulture in Europe, such as *Gypetus barbatus* [65] and *Neophron percnopterus* [66]. The low FST levels detected among native populations supported the past existence of high dispersal rates among populations. The native population of Croatia was found to be significantly differentiated from all other populations, probably because of a limited immigration rate into Croatia that, together with small population size, may quickly lead to genetic differentiation. The authors speculated that the present genetic structure is due to the recent isolation of Croatia from other populations caused by the extinction events of intermediate populations between Croatia and Ossau (France) and between Croatia and Israel, which occurred at the end of 19th century and in the 20th century, respectively.

A recent molecular study by means of microsatellite markers [67] collected the first genetic data on the Griffon vulture population from Serbia, inhabiting parts of the Balkan Peninsula and representing the last inland population adapted to the continental climate. This griffon population was compared with those from Croatia, Israel (Mediterranean climate) and the Pyrenees in France [63]. Genetic diversity was overall similar to other native populations, including Cyprus and Spain, although the population from Serbia experienced a serious bottleneck during the last decade of the twentieth century. Population structure analysis detected two genetic clusters, one grouping populations from the Balkan Peninsula and the other grouping those from Pyrenees, derived from the Spanish population. The griffon populations from Croatia and Serbia showed higher genetic diversity than those from Pyrenees, with the population of Serbia being genetically most differentiated from all other populations. The Israeli population was found to have admixed ancestry derived equally from the Balkan and the Iberian genetic clusters. Based on this evidence, the authors hypothesised that the Middle East could be recognised as the region from which European populations originated and Israel would be the remnant of the source population from which this species colonised the Mediterranean area. Indeed, it is suggested that during the Last Glacial Maximum (LGM) in Europe the European griffon vulture populations retreated to refugia in North Africa and the Arabian Peninsula. After the end of LGM, Europe was recolonised following two directions, including the way across Gibraltar into the Iberian Peninsula and the way across Bosporus into the Balkan Peninsula. The Israeli population was the only one without a recent bottleneck, a result supporting this hypothesis. Accordingly, it is plausible that during the initial colonisation of Europe from the Middle East, the populations of the Iberian and Balkan Peninsulas went through a founder effect and successive bottleneck, which resulted in the two genetic clusters mentioned above.

References

1. Wilson, M.W.; Ridlon, A.D.; Gaynor, K.M.; Gaines, S.D.; Stier, A.C.; Halpern, B.S. Ecological impacts of human-induced animal behaviour change. Ecol. Lett. 2020, 23, 1522–1536.
2. Díaz, S.; Settele, J.; Brondízio, E.S.; Ngo, H.T.; Agard, J.; Arneth, A.; Balvanera, P.; Brauman, K.A.; Butchart, S.H.M.; C han, K.M.A.; et al. Pervasive human-driven decline of life on Earth points to the need for transformative change. Scienc e 2019, 366, eaax3100.
3. Leclère, D.; Obersteiner, M.; Barrett, M.; Butchart, S.H.M.; Chaudhary, A.; De Palma, A.; DeClerck, F.A.J.; Di Marco, M.; Doelman, J.C.; Dürauer, M.; et al. Bending the curve of terrestrial biodiversity needs an integrated strategy. Nature 2020, 585, 551–556.
4. Maxwell, S.; Fuller, R.; Brooks, T.; Watson, J. The ravages of guns, nets and bulldozers. Nature 2016, 536, 143–145.
5. Tollefson, J. Humans are driving one million species to extinction. Nature 2019, 569, 171.
6. García-Jiménez, R.; Morales-Reyes, Z.; Pérez-García, J.M.; Margalida, A. Economic valuation of non-material contribut ions to people provided by avian scavengers: Harmonizing conservation and wildlife-based tourism. Ecol. Econ. 2021, 187, 107088.
7. DeVault, T.L.; Beasley, J.C.; Olson, Z.H.; Moleón, M.; Carrete, M.; Margalida, A.; Sanchez-Zapata, J.A. Ecosystem Serv ices Provided by Avian Scavengers. In Why Birds Matter; Sekercioglu, Ç.H., Wenny, D.G., Whelan, C.J., Eds.; Univ. Ch icago Press: Chicago, IL, USA, 2016; pp. 235–270.
8. Oro, D.; Margalida, A.; Carrete, M.; Heredia, R.; Doná Zar, J.A. Testing the Goodness of Supplementary Feeding to En hance Population Viability in an Endangered Vulture. PLoS ONE 2008, 3, e4084.
9. Oro, D.; Genovart, M.; Tavecchia, G.; Fowler, M.S.; Martinez-Abraìn, A. Ecological and evolutionary implications of food subsidies from humans. Ecol. Lett. 2013, 16, 1501–1514.
10. Gilbert, M.; Watson, R.T.; Ahmed, S.; Asim, M.; Johnson, J.A. Vulture restaurants and their role in reducing diclofenac e xposure in Asian vultures. Bird Conserv. Int. 2007, 17, 63–77.
11. García-Alfonso, M.; Van Overveld, T.; Gangoso, L.; Serrano, D.; Donázar, J.A. Vultures and Livestock: The Where, Wh en, and Why of Visits to Farms. Animals 2020, 10, 2127.
12. Ogada, D.L.; Keesing, F.; Virani, M.Z. Dropping dead: Causes and consequences of vulture population declines worldw ide. Year Ecol. Conserv. Biol. 2012, 1249, 57–71.
13. Moleón, M.; Sánchez-Zapata, J.A.; Margalida, A.; Carrete, M.; Owen-Smith, N.; Donázar, J.A. Humans and scavenger s: The evolution of interactions and ecosystem services. Bioscience 2014, 64, 394–403.
14. García-Jiménez, R.; Pérez-García, J.M.; Margalida, A. Drivers of daily movement patterns affecting an endangered vult ure flight activity. BMC Ecol. 2018, 18, 1–15.
15. Seibold, I.; Helbig, A.J. Evolutionary history of New and Old World vultures inferred from nucleotide sequences of the m itochondrial cytochrome b gene. Philos. Trans. R. Soc. Lond. Ser. B Biol. Sci. 1995, 350, 163–178.
16. Wink, M. Phylogeny of Old and New World Vultures (Aves: Accipitridae and Cathartidae) Inferred from Nucleotide Sequ ences of the Mitochondrial Cytochrome b Gene. Z. Naturforsch C. J. Biosci. 1995, 50, 868–882.
17. Campbell, M.O. A Fascinating Example for Convergent Evolution: Endangered Vultures. J. Biodivers. Endanger. Specie s 2014, 2, 2–4.
18. Mccormack, J.E.; Harvey, M.G.; Faircloth, B.C.; Crawford, N.G.; Glenn, T.C. A Phylogeny of Birds Based on Over 1,500 Loci Collected by Target Enrichment and High-Throughput Sequencing. PLoS ONE 2013, 8, e54848.
19. Prum, R.O.; Berv, J.S.; Dornburg, A.; Field, D.J.; Townsend, J.P.; Moriarty Lemmon, E.; Lemmon, A.R. A comprehensiv e phylogeny of birds (Aves) using targeted next-generation DNA sequencing. Nature 2015, 526, 569–573.
20. Jarvis, E.D.; Ye, C.; Liang, S.; Yan, Z.; Zepeda, M.L.; Campos, P.F.; Missael, A.; Velazquez, V.; Samaniego, J.A.; Avila-arcos, M.; et al. A Phylogeny of Modern Birds. Science 2014, 346, 1126–1138.
21. Johnson, J.A.; Brown, J.W.; Fuchs, J.; Mindell, D.P. Multi-locus phylogenetic inference among New World Vultures (Ave s: Cathartidae). Mol. Phylogenet. Evol. 2016, 105, 193–199.

22. Moreno-Opo, R.; Trujillano, A.; Arredondo, Á.; González, L.M.; Margalida, A. Manipulating size, amount and appearanc e of food inputs to optimize supplementary feeding programs for European vultures. Biol. Conserv. 2015, 181, 27–35.

23. Moreno-Opo, R.; Trujillano, A.; Margalida, A. Behavioral coexistence and feeding efficiency drive niche partitioning in E uropean avian scavengers. Behav. Ecol. 2016, 27, 1041–1052.

24. Van Overveld, T.; Blanco, G.; Moleón, M.; Margalida, A.; Sánchez-Zapata, J.A.; De La Riva, M.; Donázar, J.A. Integrati ng vulture social behavior into conservation practice. Condor 2020, 122, 1–20.

25. Moreno-Opo, R.; Trujillano, A.; Margalida, A. Larger size and older age confer competitive advantage: Dominance hiera rchy within European vulture guild. Sci. Rep. 2020, 10, 2430.

26. Ruxton, G.D.; Houston, D.C. Obligate vertebrate scavengers must be large soaring fliers. J. Theor. Biol. 2004, 228, 431 –436.

27. IUCN The IUCN Red List of Threatened Species. Available online: https://www.iucnredlist.org/ (accessed on 27 Septem ber 2021).

28. Safford, R.; Andevski, J.; Botha, A.; Bowden, C.G.R.; Crockford, N.; Garbett, R.; Margalida, A.; Ramírez, I.; Shobrak, M.; Tavares, J.; et al. Commentary Vulture conservation: The case for urgent action. Bird Conserv. Int. 2019, 29, 1–9.

29. Moreno-Opo, R.; Trujillano, A.; Margalida, A. Optimization of supplementary feeding programs for European vultures de pends on environmental and management factors. Ecosphere 2015, 6, 127.

30. Margalida, A.; Bertran, J. Copulatory behaviour in the colonial Eurasian Griffon vulture Gyps fulvus. J. Ethol. 2010, 28, 179–182.

31. Margalida, A.; Colomer, M.A.; Oro, D. Man-induced activities modify demographic parameters in a long-lived species: E ffects of poisoning and health policies. Ecol. Appl. 2014, 24, 436–444.

32. Casas-Díaz, E.; Cristòfol, C.; Cuenca, R.; Agustí, S.; Carneiro, M.; Marco, I.; Lavín, S.; Margalida, A. Determination of fl uoroquinolone antibiotic residues in the plasma of Eurasian griffon vultures (Gyps fulvus) in Spain. Sci. Total Environ. 2 016, 557–558, 620–626.

33. Herrero-Villar, M.; Velarde, R.; Camarero, P.R.; Taggart, M.A.; Bandeira, V.; Fonseca, C.; Marco, I.; Mateo, R. NSAIDs detected in Iberian avian scavengers and carrion after diclofenac registration for veterinary use in Spain. Environ. Pollu t. 2020, 266, 115157.

34. EMA. CVMP Assessment Report under Article 30 (3) of Regulation (EC) No 726/2004; European Medicines Agency: Lo ndon, UK, 2014.

35. Moreno-Opo, R.; Carapeto, R.; Casimiro, R.; Rubio, C.; Muñoz, B.; Moreno, I.; Aymerich, M. The veterinary use of diclo fenac and vulture conservation in Spain: Updated evidence and socio-ecological implications. Sci. Total Environ. 2021, 796, 148851.

36. Margalida, A.; Colomer, M.A. Modelling the effects of sanitary policies on European vulture conservation. Sci. Rep. 201 2, 2, 753.

37. Margalida, A.; Bogliani, G.; Bowden, C.G.R.; Donázar, J.A.; Genero, F.; Gilbert, M.; Karesh, W.B.; Kock, R.; Lubroth, J.; Manteca, X.; et al. One Health approach to use of veterinary pharmaceuticals. Science 2014, 346, 1296–1298.

38. Houston, D.C. Food searching in griffon vultures. Afr. J. Ecol. 1974, 12, 63–77.

39. Martin, G.R.; Portugal, S.J.; Murn, C.P. Visual fields, foraging and collision vulnerability in Gyps vultures. Ibis 2012, 15 4, 626–631.

40. Cortés-Avizanda, A.; Jovani, R.; Carrete, M.; Donázar, J.A. Resource unpredictability promotes species diversity and c oexistence in an avian scavenger guild: A field experiment. Ecology 2012, 93, 2570–2579.

41. Houston, D.C.; Cooper, J.E. The digestive tract of the whiteback griffon vulture and its role in disease transmission amo ng wild ungulates. J. Wildl. Dis. 1975, 11, 306–313.

42. Arbulu, S.; Frantzen, C.; Lohans, C.T.; Cintas, L.M.; Herranz, C.; Holo, H.; Diep, D.B.; Vederas, J.C.; Hernández, P.E. Draft Genome Sequence of the Bacteriocin-Producing Strain Enterococcus faecium M3K31, Isolated from Griffon Vultu res (Gyps fulvus subsp. fulvus). Genome Announc. 2016, 4, e00055-16.

43. Arbulu, S.; Jiménez, J.J.; Gútiez, L.; Campanero, C.; Del Campo, R.; Cintas, L.M.; Herranz, C.; Hernández, P.E. Evalua tion of bacteriocinogenic activity, safety traits and biotechnological potential of fecal lactic acid bacteria (LAB), isolated f rom Griffon Vultures (Gyps fulvus subsp. fulvus). BMC Microbiol. 2016, 16, 228.

44. Vela, A.I.; Casas-Díaz, E.; Fernández-Garayzábal, J.F.; Serrano, E.; Agustí, S.; Porrero, M.C.; Sánchez, V.; Rey, D.; Ma rco, I.; Lavín, S.; et al. Estimation of Cultivable Bacterial Diversity in the Cloacae and Pharynx in Eurasian Griffon Vultur es (Gyps fulvus). Microb. Ecol. 2015, 69, 597–607.

45. Sevilla, E.; Marín, C.; Delgado-Blas, J.F.; González-Zorn, B.; Vega, S.; Kuijper, E.; Bolea, R.; Mainar-Jaime, R.C.; Raúl Mainar-Jaime, C.C.; de Patología, D. Wild griffon vultures (Gyps fulvus) fed at supplementary feeding stations: Potentia l carriers of pig pathogens and pig-derived antimicrobial resistance? Transbound Emerg. Dis. 2020, 67, 1295–1305.

46. Mateo-Tomás, P.; Olea, P.P.; Jiménez-Moreno, M.; Camarero, P.R.; Sánchez-Barbudo, I.S.; Rodríguez Martín-Doimead ios, R.C.; Mateo, R. Mapping the spatio-temporal risk of lead exposure in apex species for more effective mitigation. Pr oc. R. Soc. B Biol. Sci. 2016, 283, 20160662.

47. Mundy, P.; Butchart, D.; Ledger, D.; Piper, S. The Vultures of Africa; R. Friedman Books in Association with the Vulture Study Group: San Diego, CA, USA, 1992.

48. Donazar, J.A. Los Buitres Ibéricos: Biología y Conservación; J.M. Reyero: Madrid, Spain, 1993.

49. Donázar, J.A.; Ceballos, O.; Tella, J.L. Communal roosts of Egyptian vultures (Neophron percnopterus): Dynamics and implications for the species conservation. In Proceedings of the Biology and Conservation of Mediterranean Raptors, P alma de Maiorca, Spain, 22–25 September 1994; SEO BirdLife: Madrid, Spain, 1996; pp. 190–201.

50. Buechley, E.R.; Şekercioğluab, Ç.H. The avian scavenger crisis: Looming extinctions, trophic cascades, and loss of crit ical ecosystem functions. Biol. Conserv. 2016, 198, 220–228.

51. Swan, G.; Naidoo, V.; Cuthbert, R.; Green, R.E.; Pain, D.J.; Swarup, D.; Prakash, V.; Taggart, M.; Bekker, L.; Das, D.; e t al. Removing the Threat of Diclofenac to Critically Endangered Asian Vultures. PLoS Biol. 2006, 4, e66.

52. Green, R.E.; Taggart, M.A.; Das, D.; Pain, D.J.; Sashi Kumar, C.; Cunningham, A.A.; Cuthbert, R.; Green, R.E. Collaps e of Asian vulture populations: Risk of mortality from residues of the veterinary drug diclofenac in carcasses of treated c attle. J. Appl. Ecol. 2006, 43, 949–956.

53. Green, R.E.; Donázar, J.A.; Sánchez-Zapata, J.A.; Margalida, A. Potential threat to Eurasian griffon vultures in Spain fr om veterinary use of the drug diclofenac. J. Appl. Ecol. 2016, 53, 993–1003.

54. Moreno-Opo, R.; Margalida, A.; García, F.; Arredondo, Á.; Rodríguez, C.; González, L.M. Linking sanitary and ecologic al requirements in the management of avian scavengers: Effectiveness of fencing against mammals in supplementary f eeding sites. Biodivers. Conserv. 2012, 21, 1673–1685.

55. Adawaren, E.O.; Mukandiwa, L.; Njoya, E.M.; Bekker, L.; Duncan, N.; Naidoo, V. The use of liver slices from the Cape v ulture (Gyps coprotheres) to better understand the role of liver toxicity of non-steroidal anti-inflammatory drugs (NSAID s) in vultures. Environ. Toxicol. Pharmacol. 2018, 62, 147–155.

56. Plaza, P.I.; Lambertucci, S.A. What do we know about lead contamination in wild vultures andcondors? A review of dec ades of research. Sci. Total Environ. 2019, 654, 409–417.

57. Cortés-Avizanda, A.; Donázar, J.A.; Pereira, H.M. Top Scavengers in a Wilder Europe. In Rewilding European Landsca pes; Pereira, H.M., Navarro, L.M., Eds.; Springer International Publishing: Cham, Switzerland, 2015; pp. 85–106. ISBN 978-3-319-12039-3.

58. Donázar, J.A.; Margalida, A.; Campión, D. Vultures, feeding stations and sanitary legislation: A conflict and its consequ ences from the perspective of conservation biology. In Munibe 29; Sociedad de Ciencias Aranzadi: Donostia, Spain, 20 09; pp. 1–551.

59. Margalida, A.; Donazar, J.; Carrete, M.; Sanchez-Zapata, J. Sanitary versus environmental policies: Fitting together two pieces of the puzzle of European vulture conservation. J. Appl. Ecol. 2010, 47, 931–935.

60. Oaks, J.L.; Martin, G.; Virani, M.Z.; Watson, R.T.; Meteyer, C.U.; Rideout, B.A.; Shivaprasad, H.L.; Ahmed, S.; Chaudhr y, M.J.I.; Arshad, M.; et al. Diclofenac residues as thecause of vulture populationdecline in Pakistan. Nature 2004, 427, 630–633.

61. Mereu, P.; Pirastru, M.; Satta, V.; Frongia, G.N.; Kassinis, N.; Papadopoulos, M.; Hadjisterkotis, E.; Xirouchakis, S.; Ma nca, L.; Naitana, S.; et al. Mitochondrial D-loop Sequence Variability in Three Native Insular Griffon Vulture (Gyps fulvu s) Populations from the Mediterranean Basin. Biomed Res. Int. 2019, 2019, 2073919.

62. Mira, S.; Billot, C.; Guillemaud, T.; Palma, L.; Cancela, M.L. Isolation and characterization of polymorphic microsatellite markers in Eurasian vulture Gyps fulvus. Mol. Ecol. Notes 2002, 2, 557–558.

63. Le Gouar, P.; Rigal, F.; Boisselier-Dubayle, M.C.; Sarrazin, F.; Arthur, C.; Choisy, J.P.; Hatzofe, O.; Henriquet, S.; Lécuy er, P.; Tessier, C.; et al. Genetic variation in a network of natural and reintroduced populations of Griffon vulture (Gyps f ulvus) in Europe. Conserv. Genet. 2008, 9, 349–359.

64. Le Gouar, P.; Robert, A.; Choisy, J.-P.; Henriquet, S.; Lecuyer, P.; Tessier, C.; Sarrazin, F. Roles of survival and dispers al in reintroduction success of griffon vulture (Gyps fulvus). Ecol. Appl. 2008, 18, 859–872.

65. Gautschi, B.; Mü Ller, J.P.; Schmid, B.; Shykoff, J.A. Effective number of breeders and maintenance of genetic diversity in the captive bearded vulture population. Heredity 2003, 91, 9–16.

66. Kretzmann, M.B.; Capote, N.; Gautschi, B.; Godoy, J.A.; Donázar, J.A.; Negro, J.J. Genetically distinct island populations of the Egyptian vulture (Neophron percnopterus). Conserv. Genet. 2003, 4, 697–706.
67. Davidović, S.; Jelić, M.; Marinković, S.; Mihajlović, M.; Tanasić, V.; Hribšek, I.; Sušić, G.; Dragićević, M.; Stamenković-Radak, M. Genetic diversity of the Griffon vulture population in Serbia and its importance for conservation efforts in the Balkans. Sci. Rep. 2020, 10, 1–12.